Design of a Reducing Motion For an 8x10 Westinghouse Gas Engine

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Design and Construction of a Reducing Motion for an 8 x 10 Westinghouse Gas Engine.

A Thesis Presented

by

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to the

President and Faculty

of

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for the Degree

of

Batchelor of Science in Mechanical Engineering,

having completed the prescribed course of study

in

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Design and Construction

# of a

Reducing Motion for an

8 x 10 Westinghouse Vertical, Three Cylinder,

Four Cycle, 35 H.P. Gas Engine.

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Introduction.

The engine for which this reducing motion was designed is a Westinghouse Vertical, 3 cylinder, four cycle 8 x 10 gas engine as shown in Fig. 1. It has a rating of 35 H.P. at a speed of 325 R.P.M. The present method of indicating the power of this engine is not satisfactory or thorough and has many objectionable features. For this reason it was decided to design and construct a mechanism which would overcome the difficulties now prevalent. The method now used is shown in Fig. 13 and consists in attaching an indicator to one cylinder only, and in operating this indicator by means of a cord running across the top of the engine, over a pulley, and down to the upper end of a vertical rod which passes through two guides. This rod is situated just above the end of the engine shaft and is actuated by a small crank on the end of the shaft. The crank for operating this mechanism lies in the same plane as the crank of the cylinder from which cards are being taken. To take cards from either of the other cylinders it is necessary to shift the position of the crank on the end of the shaft through an angle of 120 degrees, the direction of shifting depending upon which cylinder the cards are to be taken from. If the ratio of the crank operating the indicator to its connecting rod is the same as the ratio of the engine crank to its connecting rod, then the vertical rod will have the same relative motion as the piston.

In calculating the power of the engine it is assumed that the same amount of work is done in each of the other two cylinders as is represented by the cards taken from the one cylinder. This arrangement has the following distinctive features which are detrimental to its adoption.

1. The indicator cord is necessarily long (five or six feet) and errors are bound to be introduced due to the stretch of the cord and the inertia of the indicator drum.
2. The assumption that the same amount of work is done in each cylinder is not necessarily true as the mechanical construction of one of the cylinders might differ from one of the others. A difference in the amount of clearance would cause a variation of the amount of power developed.
3. This method of taking cards from one cylinder at a time does not allow for a change of conditions either in the gas or in the engine. Cards taken simultaneously from the three cylinders would be obtained under the same conditions even though the conditions of operation were constantly changing.

Object.

The object sought was

1. To design and construct a mechanism which would

operate three indicators simultaneously, and at the same time eliminate the errors due to a long indicator cord.

2. To actuate this mechanism in such a manner as to avoid errors due to lost motion in the transmission.

In the design it was assumed that the cards would be three inches long and that the speed of the engine would be 300 R.P.M.

Method of Design.

After a careful consideration of the various methods by which these indicators might be operated, it was decided that a small shaft caused to rotate at the same speed as the main engine shaft, could best give the proper motion to the indicators, either by means of cams, cranks or eccentrics. The shaft to be run horizontally along the rear of the engine, supported by means of cast iron standards bolted to the crank case, and driven by means of a silent chain and sprockets. The two shaft standards lying between the cylinders to be extended upward and have attached to them guides for the rods which operate the indicators; these rods in turn to be operated from the shaft. If cams were used to operate these rods it was found that there would be a possibility of error in the indicator cards due to the inertia of the moving parts, as the speed of the engine is normally high. A correct movement could be obtained by means of cranks, but to insert three center cranks in a light shaft with an angle of 120 degrees

between them, would not only make a complicated mechanism hard to construct, but would also present a difficult problem when it came to adjusting the cranks and aligning the shaft. The decision to use eccentrics overcame most of the difficulties encountered in the two former methods, in that a straight shaft all in one piece could be used, any eccentric could be adjusted independently of the others, and the drive of the indicator rods would be positive at all times. This construction wouldalso be much simpler

The location of the shaft and its method of drive were the next problems to present themselves. It was decided that the most convenient and out-of-the-way place would be just back of the cylinders parallel to the main shaft and about six inches above the crank case, as shown in Fig. 1. It was also decided to support the shaft by cast iron standards bolted to the crank case, and to drive the shaft by means of a Renold Silent Chain and sprockets manufactured by the Link Belt Machinery Co. of Chicago. This method of drive was adopted because it would give a positive velocity ratio which would not be affected by wear if the chain were kept taut.

Sprockets.

The sprockets (Fig.2) were designed to be each twelve inches in diameter and the chain 1/2" wide by 5/8" pitch. The reason for the large size sprockets was that in case there was any error introduced due to slack in the chain, it would be greatly reduced

by increasing the size of the sprockets. The driver sprocket was designed to have an offset hub so that the chain might run as close to the engine as possible. The hub was 2" long with a 3-3/ " bore and was fastened to the shaft by set screws. The driven sprcket was of the same diameter with the hub set centrally, bored to 1/2" and attached to the shaft by means of set screws.

Shaft.

In the design of the shaft it was desired to keep it as small as possible and at the same time to give it sufficient size to have the proper rigidity. The size of the eccentrics being governed by the size of the shaft, was another reason for keeping the shaft small, as the space which the eccentrics must occupy is limited. The power required to operate an indicator was measured by means of a spring balance and was found to be approximately 4#, which for the three indicators operating at the same time would make a total of 12#. As was mentioned, the card was assumed to be 3" long, therefore the eccentricity of the eccentrics would have to be 1-1/2". The 12# of the three indicators acting at a distance of 1-1/2" from the center of the shaft would give a torque of 12 x 1-1/2 or 18 inch pounds. The angle of deflection was calculated from Clark's formula which is

$$n = \frac{180 \times 32 \times TL}{C\ D^4} = 583.61 \frac{T\ L}{C\ D^4}$$

where T is the torque in inch pounds, L the length of shaft in

inches, D the diameter in inches, and C the modulus of transverse elasticity of the material of which the shaft is composed. The value of C used for steel is 11,000,000. Assuming a 1/4" shaft to be of sufficient size the substitutions were made in the formula as follows;

$$n = 583.61 \frac{18 \times 27}{11,000,000\ (.25)^4} =$$

$$\frac{583.61 \times 18 \times 27 \times 256}{11,000,000} = 6.6^{\circ} \text{ deflection for } 27''.$$

This is the length from the driven sprocket to the first two eccentrics as shown in Fig.1. In the calculation the third eccentric which was located 15" from the first two, was assumed to act with these two in producing the deflection. Clark states that a deflection of 1° in 20 diameters is the working limit for the deflection of a shaft. This calculation gives 6.6° deflection for 27 x 4 = 108 diameters, which gives 1.6° for 20 diameters. This deflection is past the working limit and would introduce serious error if allowed. In fact, for this particular case, the deflection should be much smaller than would be allowed in an ordinary case of power transmission. The next assumption was that the shaft should be 1/2" and the substitutions were made in the above formula giving

$$n = \frac{583.61 \times 18 \times 27}{11,000,000\ (.5)^4}$$

$$= \frac{583.61 \times 18 \times 27 \times 16}{11,000,000} \quad .41^{\circ} \text{ deflection for } 27''.$$

From this calculation we get .41° deflection for 54 diameters or .15° for 20 diameters, which is well within the safe limit.

Shaft Supports.

The shaft was to be supported in three places. One of the supports was a corner bracket overhanging the frame of the engine and extending out a sufficient distance to support the end of the shaft near the sprocket. This sprocket must be out a distance sufficient to line up with the driver sprocket, which was placed as close to the engine bearing as possible. The corner bracket (Fig.3) was made of cast iron with webbs of 1/2" thickness. On the front face was placed a lug 2" x 2-1/4" which was milled off to furnish a seat for the journal bearing. The other two supports (Fig.8) were of different design and serve a two fold purpose. They consist of a cast iron plate 1/2" thick supported on a base of like material and thickness, with a web 1/4" thick 4" wide at the bottom and tapering off at the top. These standards have three lugs each, the lower ones furnishing seats for shaft bearings and the others seats for the guides of the indicator rods (Figs. 9 & 11). These standards were milled off and bolted down to the engine frame with cap bolts.

Eccentrics.

The eccentrics (Figs. 6 & 7) consist of a cast iron sheave

4-1/4" x 3/8" with a rectangular groove in the center 3/16" wide, into which a brass eccentric strap is fitted. The strap is in two parts which are held together by bolts which pass through lugs on each side. The eccentric rods Fig.5, were made from 1/4" steel shafting. The connection of these eccentric rods to the indicator rods was made to an extended pivot on the indicator rod, which was connected between the guides, thus giving greater rigidity than if connected outside the guides.

Indicator Rods.

The indicator rods (Fig.5) were also made of 1/4" steel shafting and are held in a vertical position by cast iron guides (Figs. 9 & 11) bolted to the shaft supports. The cords from the indicators pass over small pulleys and fasten to the tops of these rods. The guides for the indicator rods were put on by forming a tongue in them which fitted a corresponding groove seats. They were then fastened on with cap screws.

Shaft bearings.

The shaft bearings (Fig. 10) were made of cast iron unbabbitted, each furnishing a direct support for 2" of the shaft. They were cast in two parts which were faced off, bolted together with four cap screws and then drilled bored and reamed to 1/2". Each bearing was fastened to its standard by two cap screws and two dowel pins.

Workmanship.

All patterns and castings were made in the shops of Armour Institute of Technology as was also the machine work. The Renold silent chain and sprockets were purchased from the Link Belt Co.

Erection.

The mechanism was erected by first putting in its proper place the corner bracket at a sufficient distance from the main engine shaft and at sufficient distance from the main engine shaft so that no slack would remain in the chain. The side of the crank case against which this was to rest being a cast surface only and uneven, it was found necessary to fill in around it with babbitt metal, which was melted and poured in after stopping up around the edges with fire clay. Next the standard at the opposite end of the shaft was lined up with the corner bracket, and then by means of a straight edge the middle support was brought into line. The shaft was then placed in position and lined by means of a surface gauge. The fly-wheel of the engine was removed and the driver sprocket placed next to the bearing, after which the fly-wheel was again put in place. The driven sprocket was lined up with the driver and the chain mounted.

Adjustments.

The adjustments consisted in placing the eccentrics in the same relative positions as the engine cranks. For example, the eccentric of cylinder #1 must be in its lowest position when

the piston of cylinder #1 is in its lowest position. To accomplish this it was necessary to make each adjustment separately. The ignitor was removed and a surface gauge placed on the piston with its pointer opposite a vertical scale which rested on top of the cylinder. The eccentric was set as near as possible by guess and then the engine was turned backward off dead center by about 30 degrees, the reading on the scale being noted, and by means of dividers the mark was made on the indicator rod any given distance from a fixed point on the guide. The engine was now turned forward until the gauge point again coincided with the same scale reading. With the dividers set for the same distance another mark was made on the indicator rod from the given point. If the eccentrics were in the correct position the two marks on the rod would coincide, but if not then the eccentric had to be shifted so that the divider point would fall half way between the marks, and new readings taken. The engine was always turned in the same direction in order to have the same conditions with relation to slip, backlash etc. This was repeated for each cylinder until the eccentrics were in the same position as their respective cranks.

Data.

To get comparative data the two mechanisms operating the eccentrics were arranged so that cards could be taken from the first cylinder by either method. A load of 150# was put upon the engine by means of a Prony brake and kept constant all the time

cards were being taken. A Crosby Indicator fitted with a 240# spring was attached to cylinder #1. Several cards were taken using both reducing motions. The cards were integrated and showed the following results;

Old Reducing Motion.

Area of Card	Length	M. E. P.
.95	3.09	73.75
.94	3.07	73.48
.96	3.08	74.83

New Reducing Motion.

.86	2.98	64.25
.78	2.85	65.69
.85	2.98	68.50
.84	2.98	67.65

The mean effective pressure was obtained by dividing the area of the card by its length and then multiplying by the scale of the indicator spring; which in this case was 240#. Both these mechanisms weredesigned to give a 3" card but it will be noted that the old reducing motion gives a card longer than 3" while the new one give one practically 3" long. Thus it is shown that the error due to a long indicator cord is considerable. The following are samples of the cards taken;

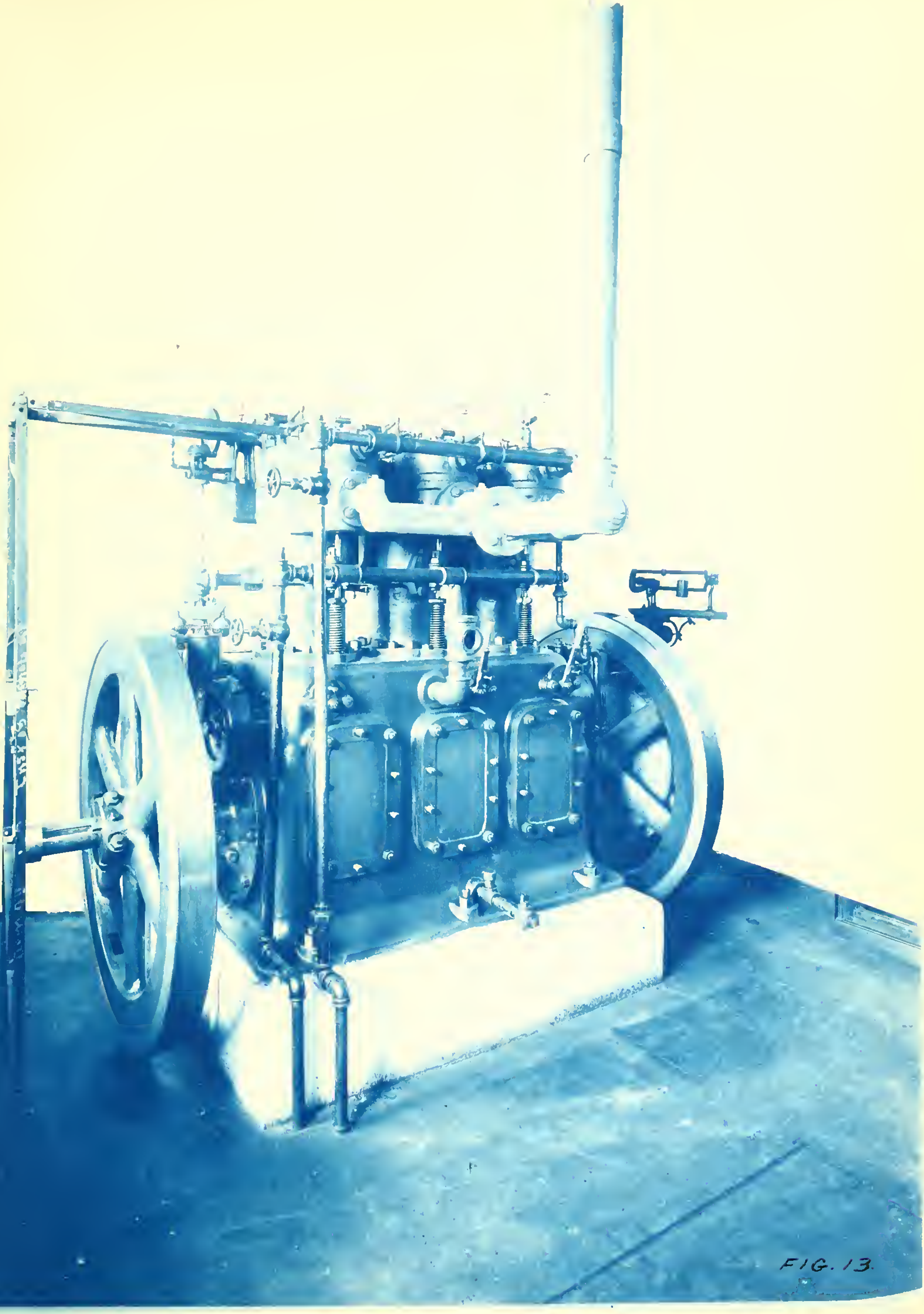


FIG. 13.

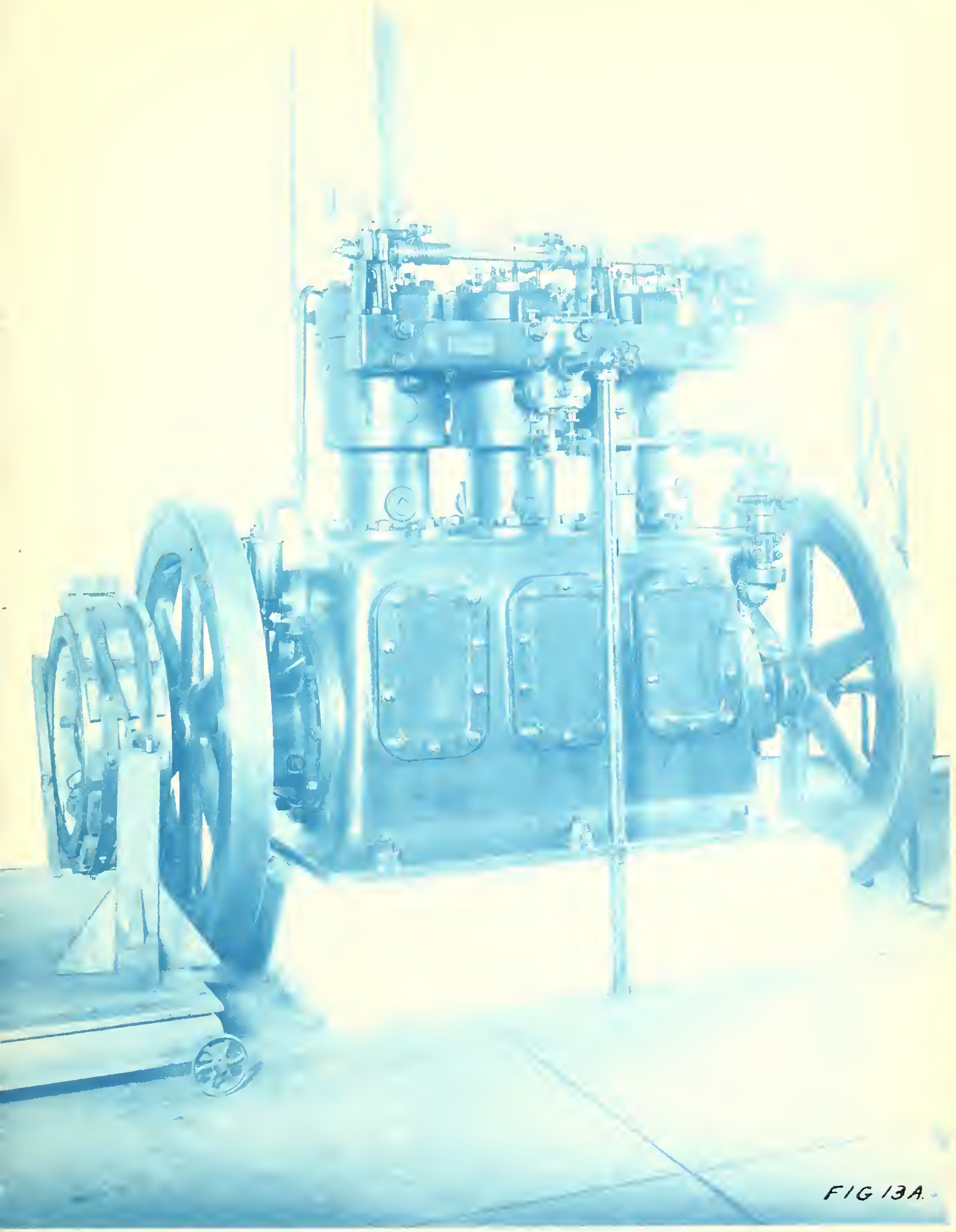
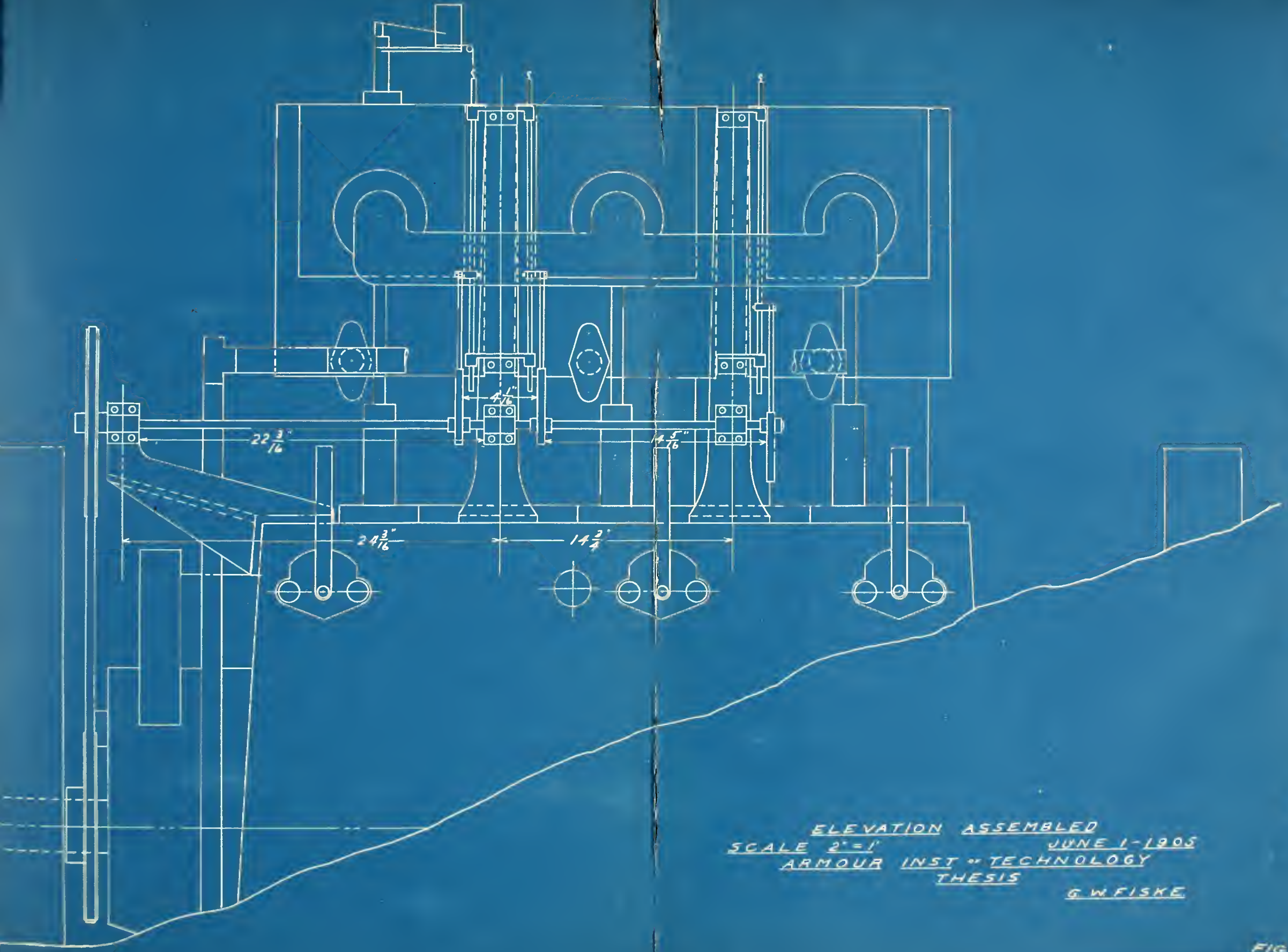


FIG 13A.



ELEVATION ASSEMBLED
SCALE 2" = 1'
JUNE 1-1905
ARMOUR INST of TECHNOLOGY
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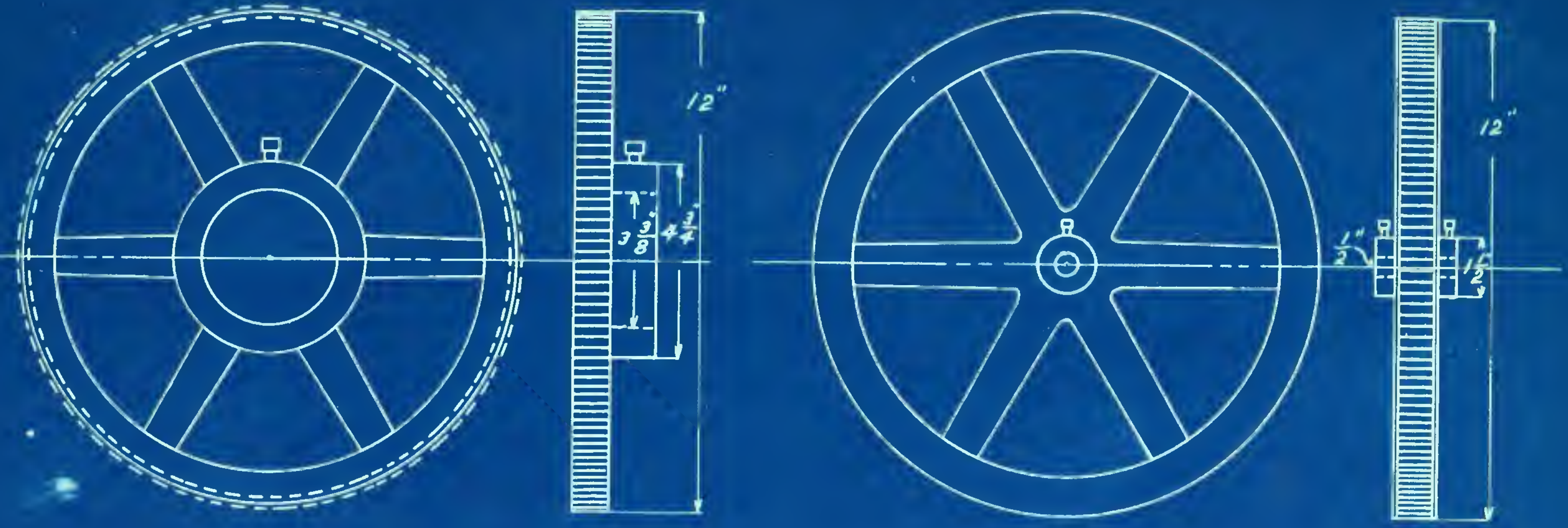
FIG. 1



CHAIN SPROCKETS
SCALE 3" = 1' JUNE 1 1905
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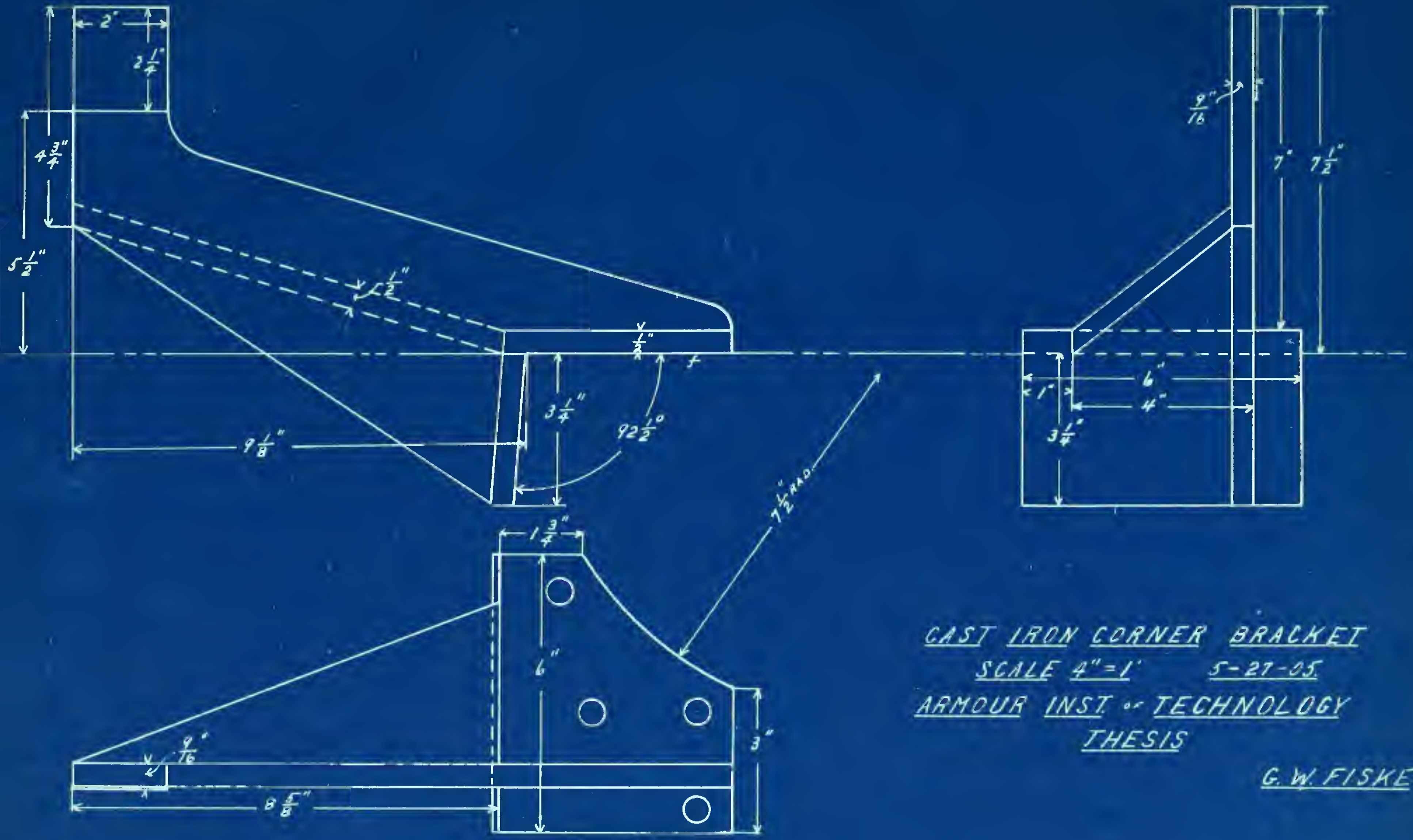
FIG. 2



CAST IRON CORNER BRACKET
SCALE 4"=1' 5-27-05.
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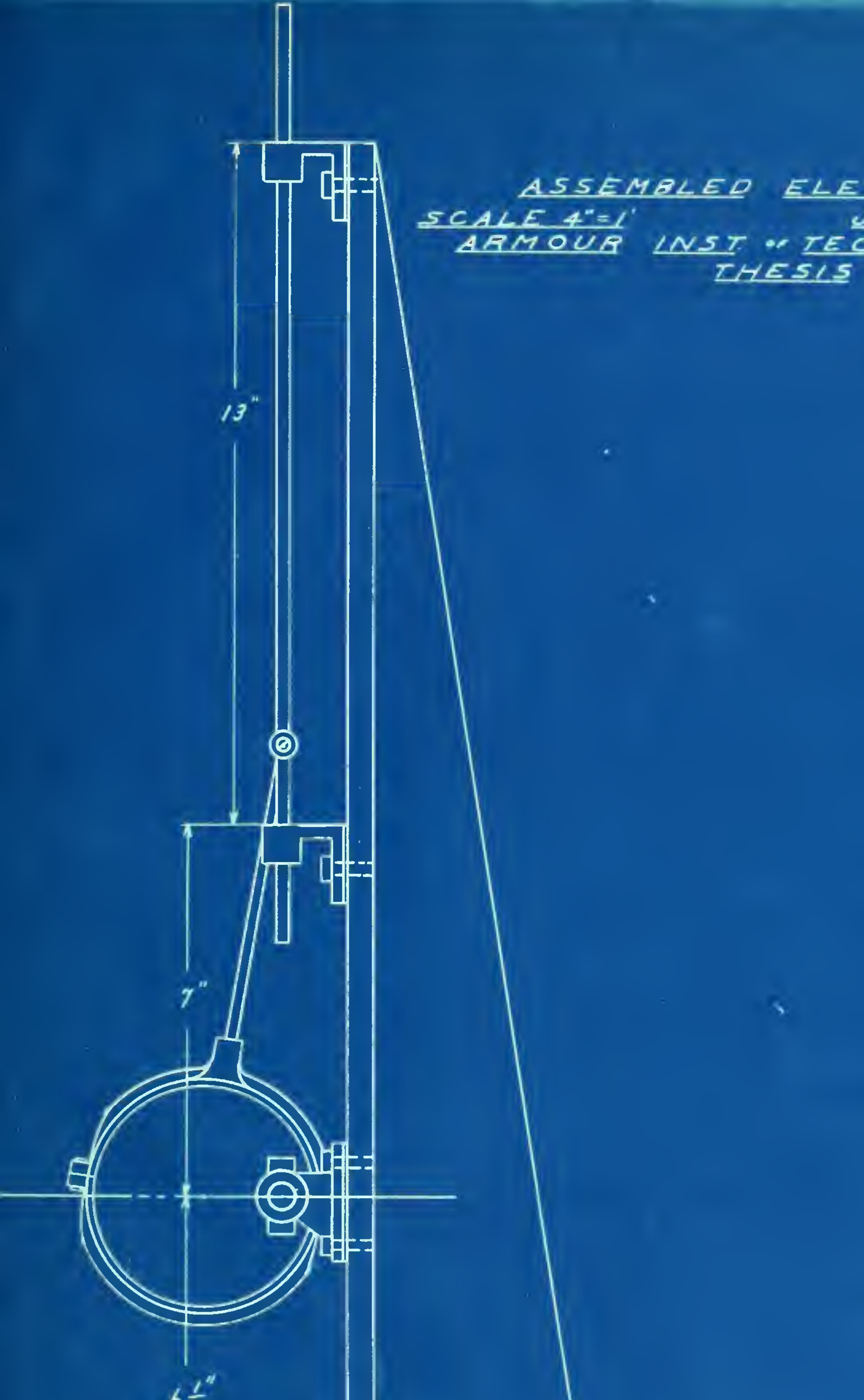
FIG. 3



ASSEMBLED ELEVATION
SCALE 4"=1' JUNE 1-1905
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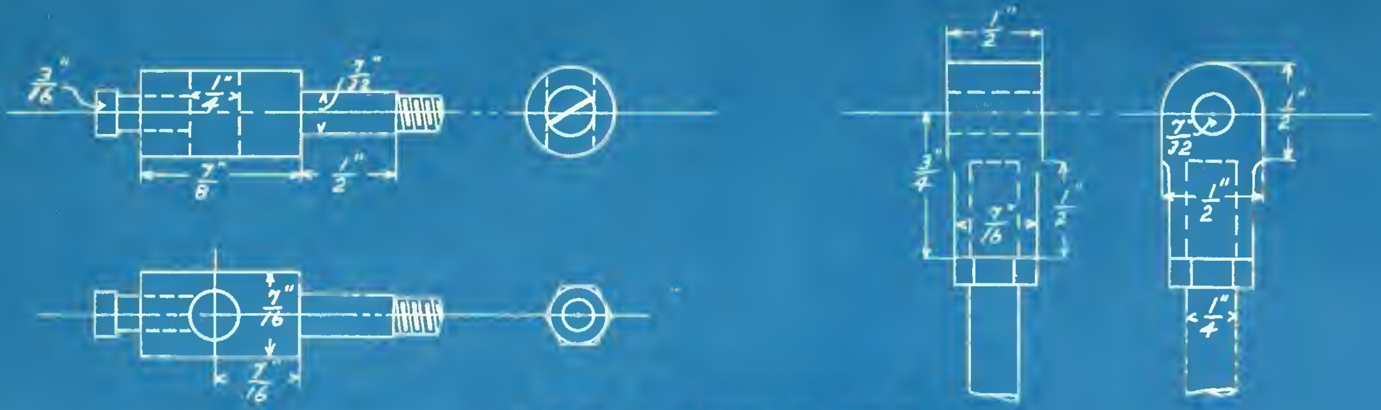
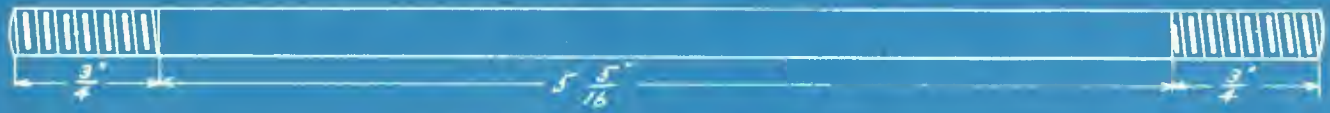
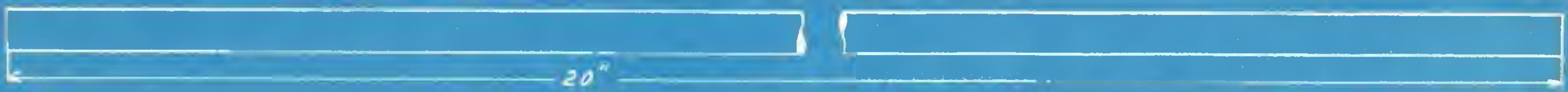
FIG 4



ROD CONNECTORS



CONNECTING ROD



INDICATOR ROD

RODS AND CONNECTIONS
SCALE 12" = 1'   JUNE 1 - 1905
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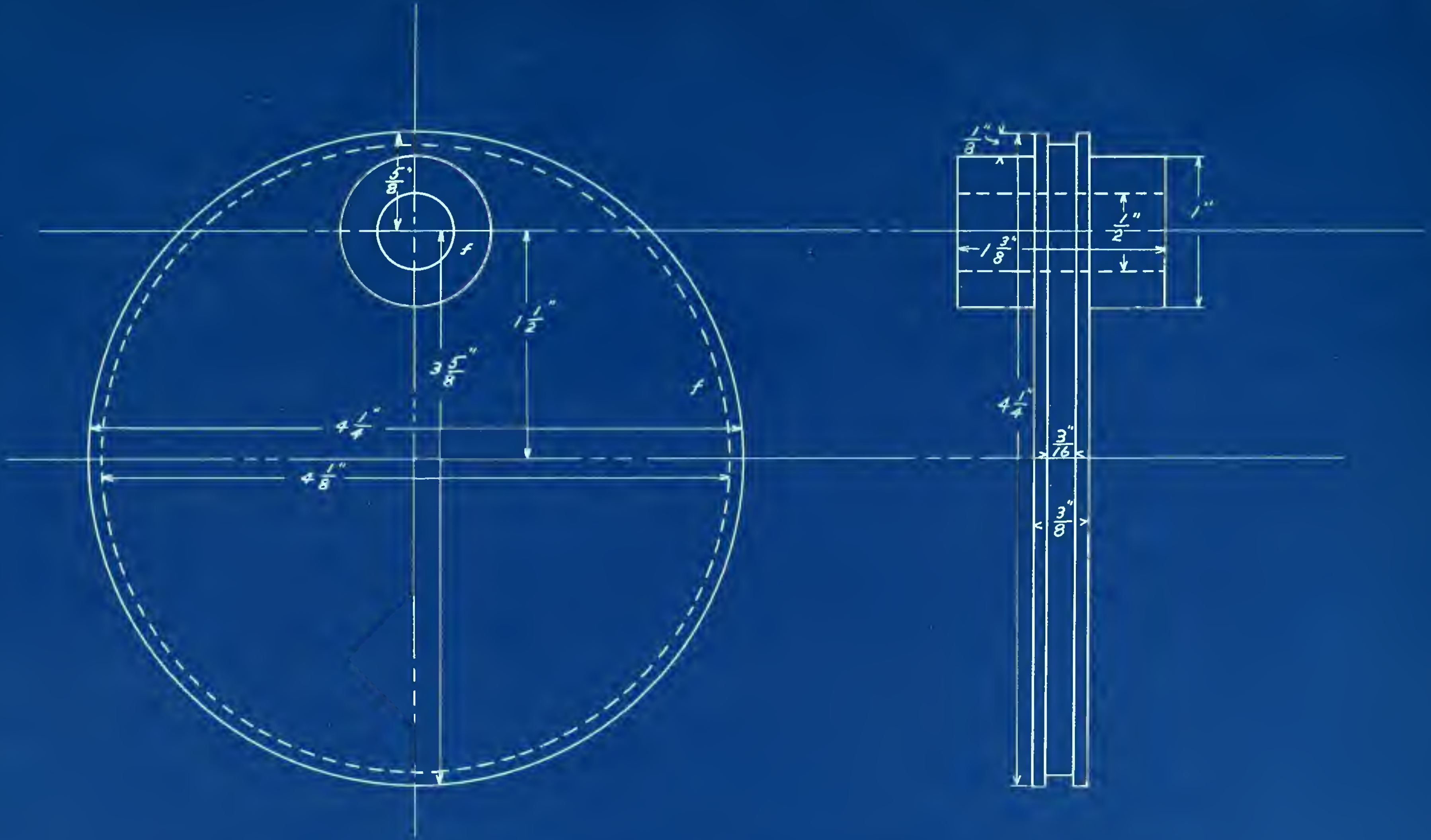
FIG. 5



ECCENTRIC SHEAVE
SCALE 12" = 1' JUNE 1 - 1905
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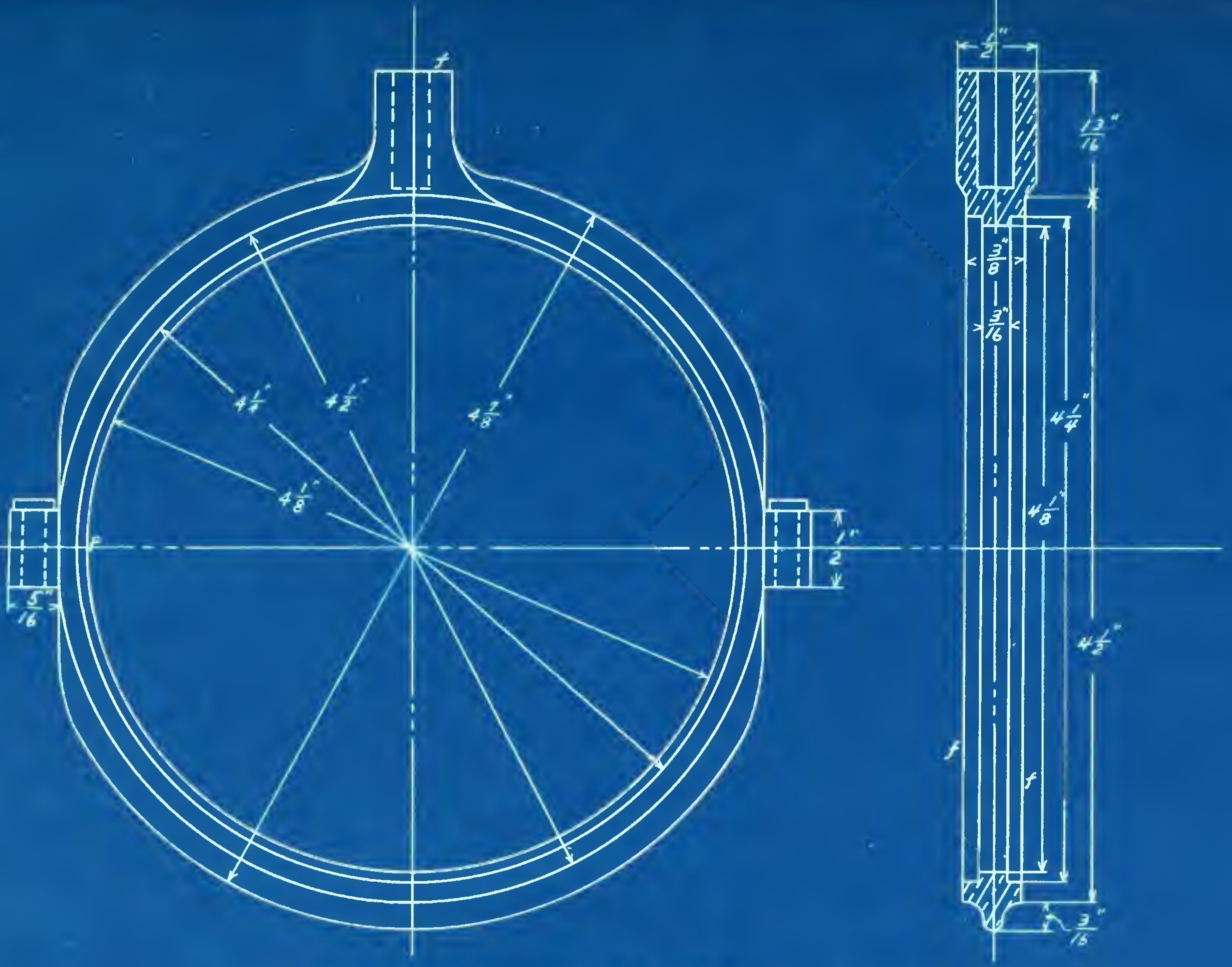
FIG 6



ECCENTRIC STRAP

SCALE 12" = 1'
JUNE 1 - 1905

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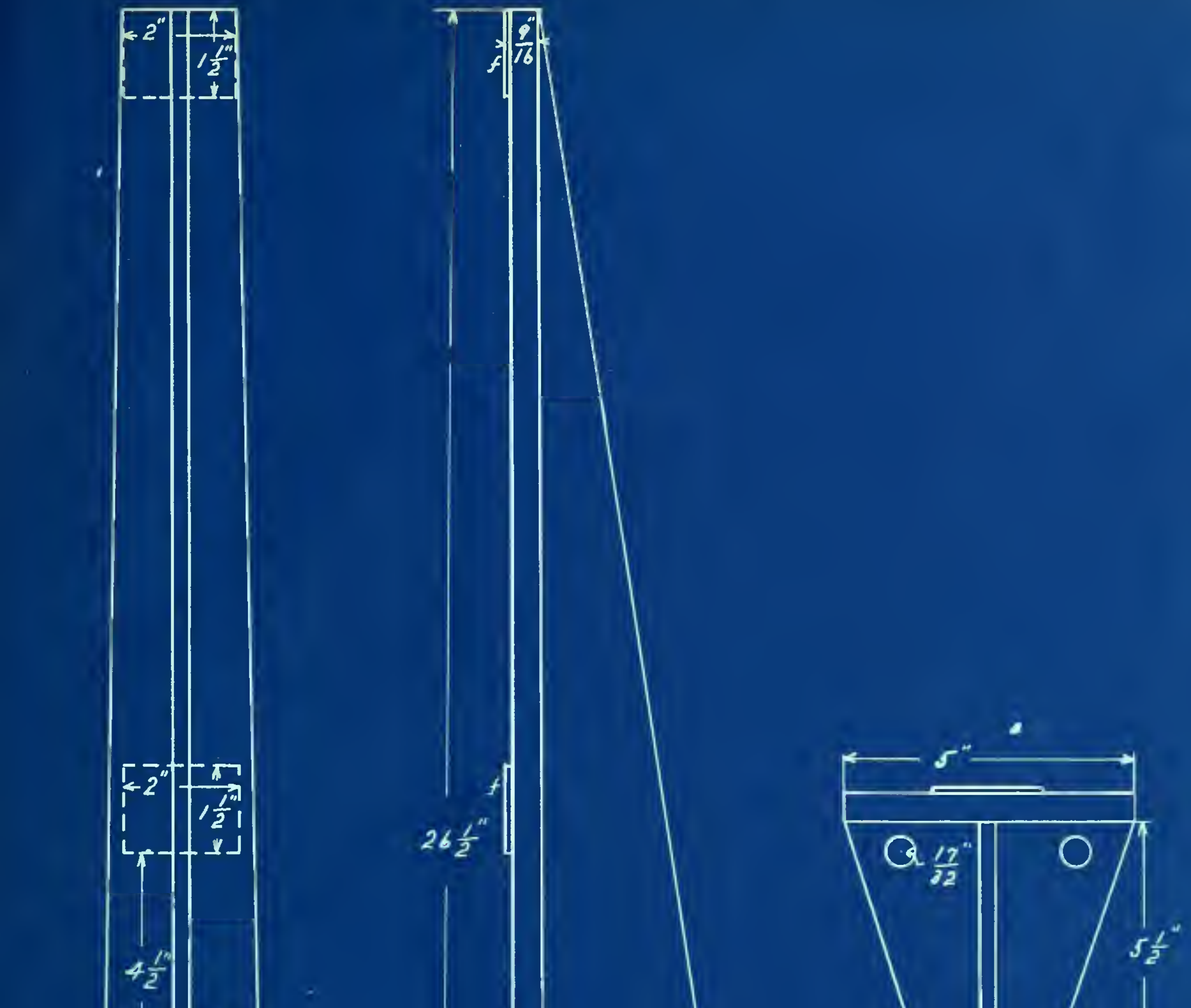
FIG. 7



CAST IRON SHAFT SUPPORTS
SCALE 4"=1'   JUNE 1-1905
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THESIS

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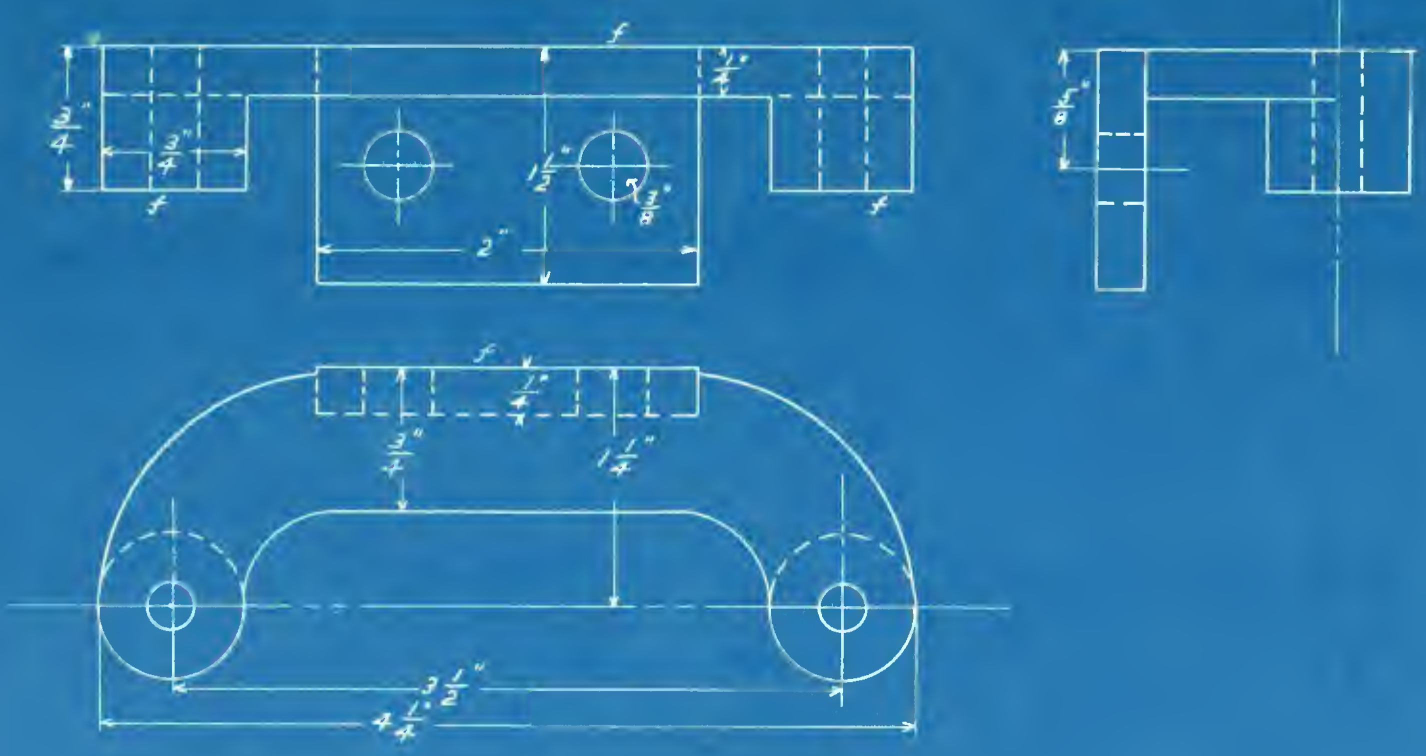
FIG 8



INDICATOR ROD GUIDES
SCALE 12"=1' JUNE 1-1905
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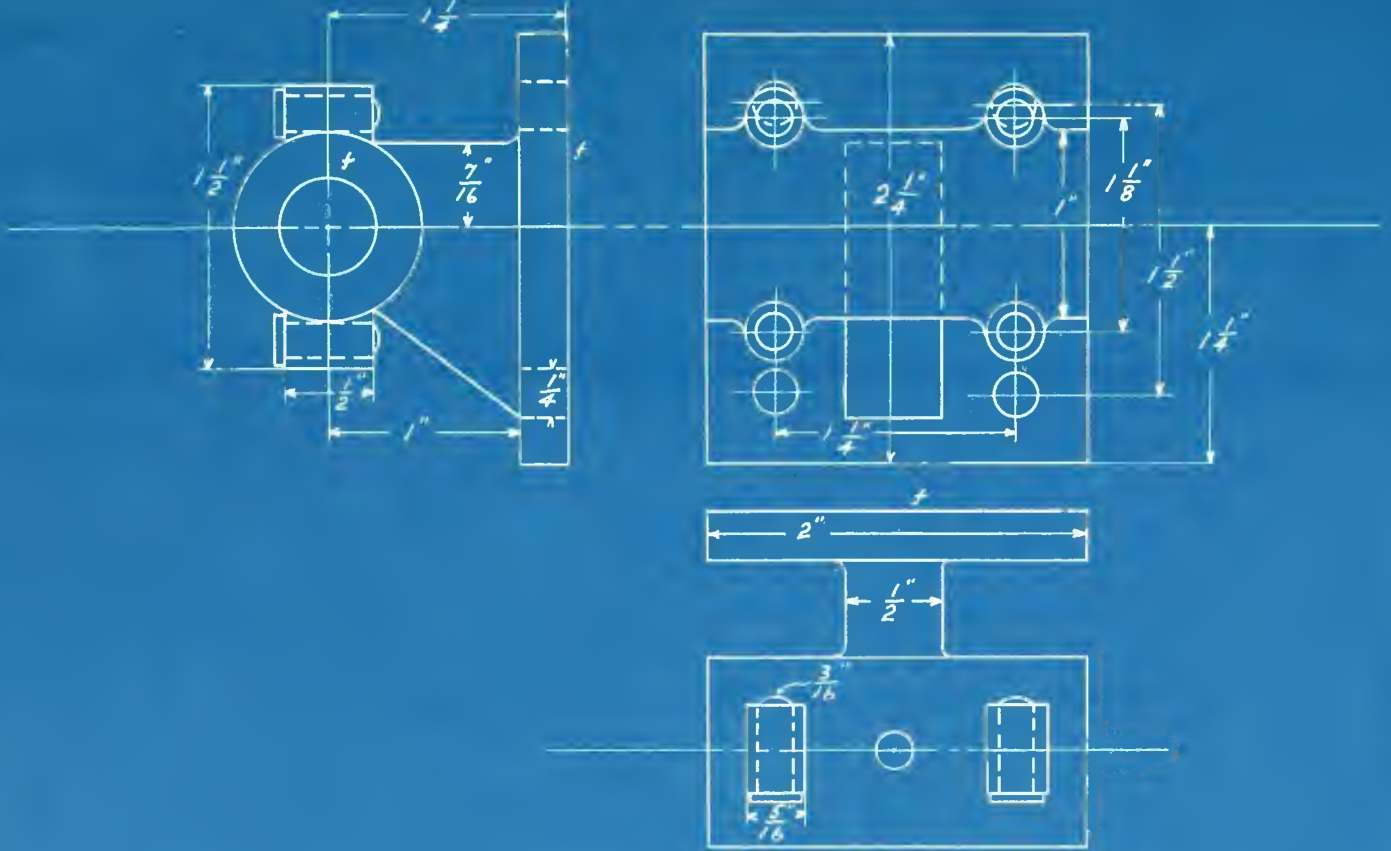
FIG 9



SHAFT BEARING
SCALE 12"=1' JUNE 1 - 1905
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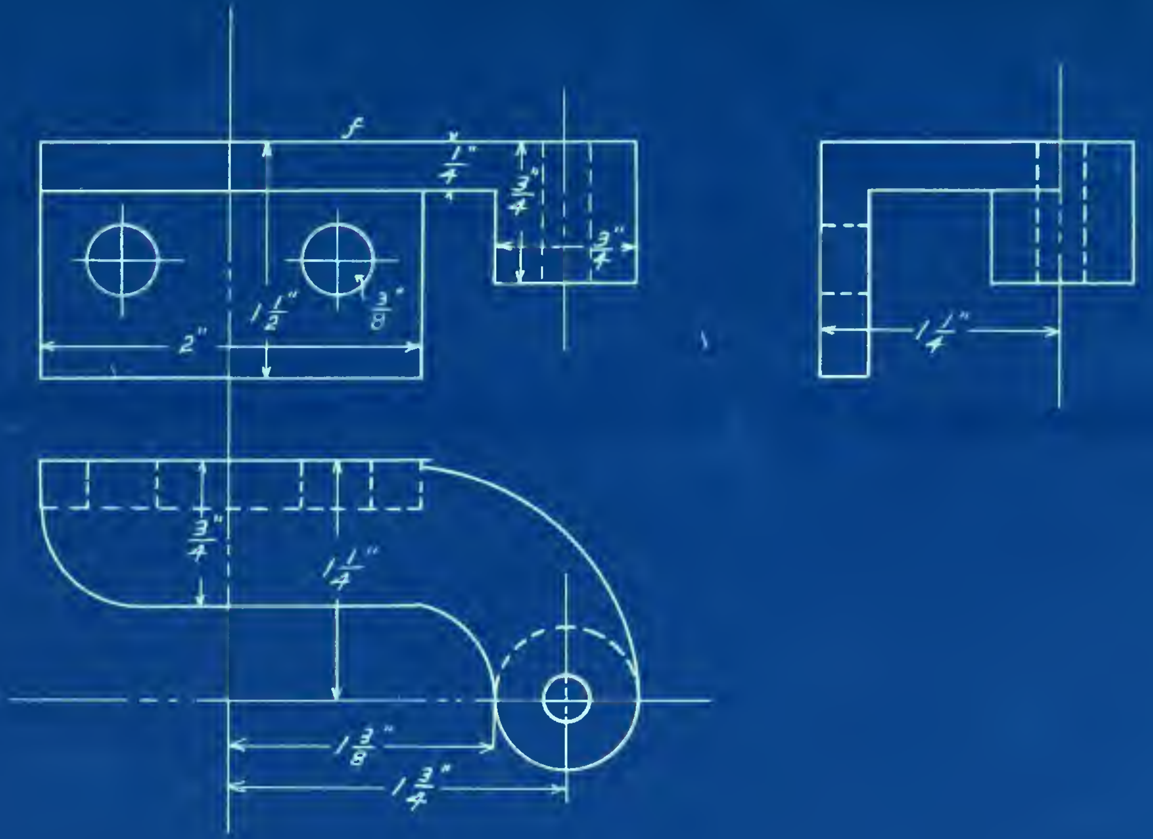
FIG 10



INDICATOR ROD GUIDES
SCALE 12"=1' JUNE 1-1905
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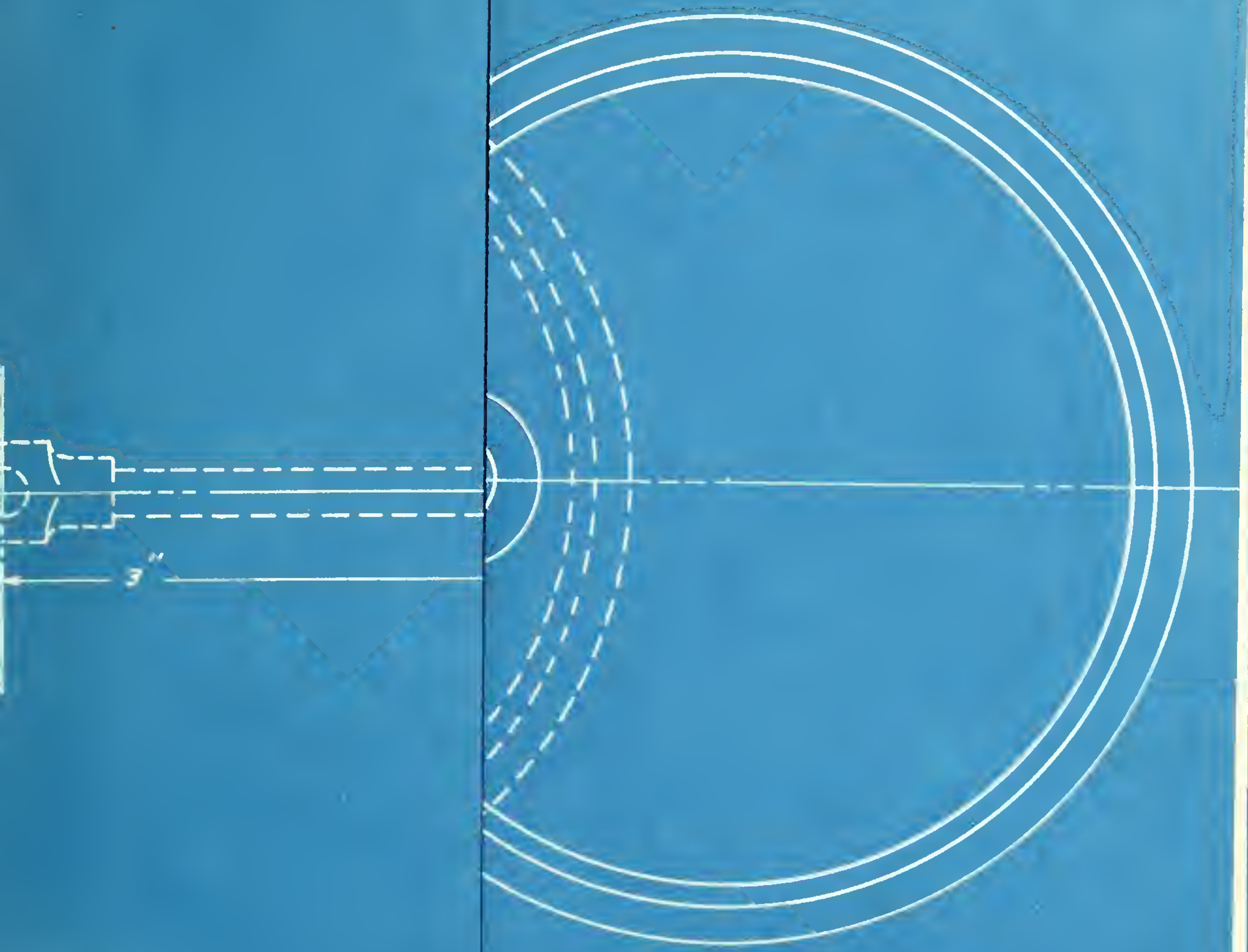
FIG. 11



SSEMBLED
JUNE 1 - 1905
TECHNOLOGY
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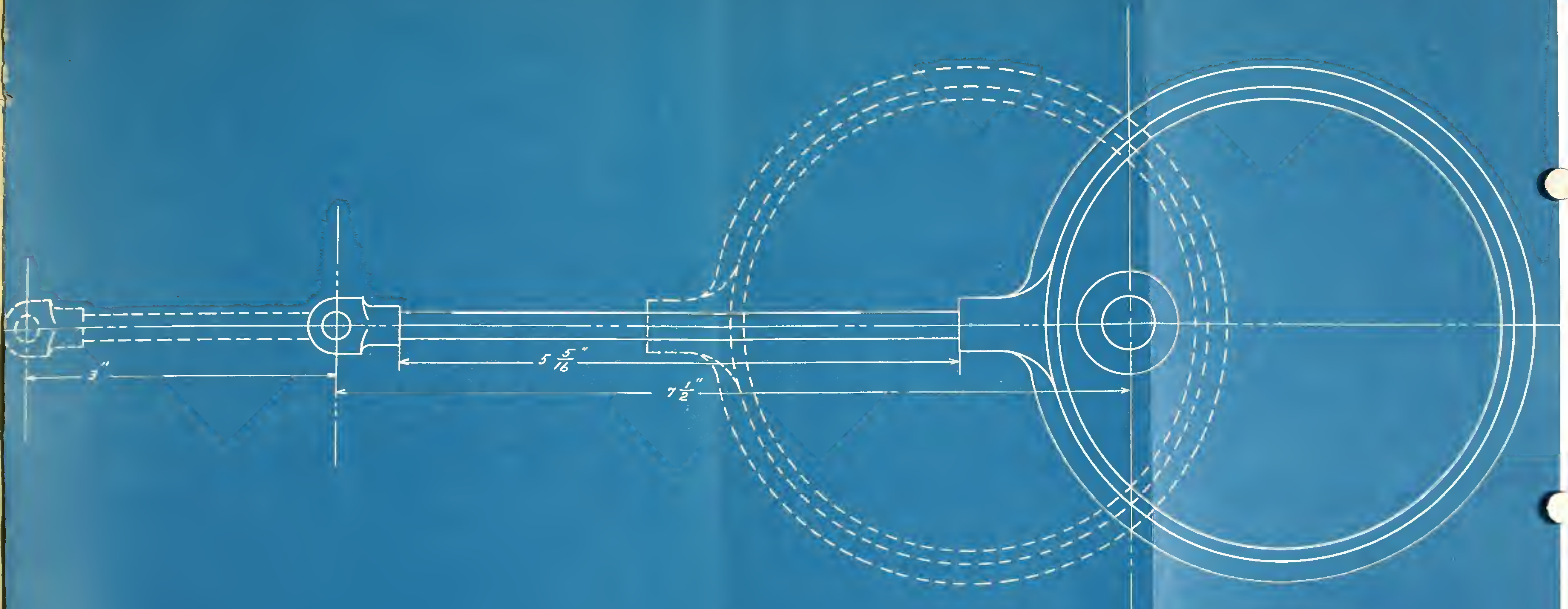
FIG. 12



ECCENTRIC ASSEMBLED
SCALE 12"=1' JUNE 1-1905
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FIG. 12